Polyester Mesh Capability Study with UV Inks

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The ability of polyester fabric to produce a uniform, controlled and repeatable deposit thickness becomes important to the screen printer interested in continually producing a high quality printed product, and it becomes critical when attempting to control properties such as color and appearance, electronic values and weatherability of that printed product.

Process control of wet and dry ink deposit thickness and uniformity is fundamental to establishing consistency throughout the print run in the areas mentioned above, not to mention reproducing the desired characteristics when the job is reprinted at a later time. With the demand for high quality screen printing increasing and competition growing in the industry, greater process control will become necessary to maintain a cutting edge in the marketplace.

In light of this, the Screen Printing Technical Foundation has completed a capability study on nine polyester fabrics of different mesh counts printed with UV inks. The areas of interest included in this study are the thickness of deposit (both wet and cured), the uniformity of deposit, the effect of five UV inks from different manufacturers, and the level of control achieved with a computer controlled screen printing press as compared with a manual screen printing setup.

An examination of polyester screen mesh was pursued due to the fact that it is one of the most, if not the single most, influencing factor on ink deposit in the screen printing process. By evaluating the performance of the mesh under controlled conditions a good picture of the screen's process capability and degree of influence on ink deposit can be determined.

With a greater understanding of polyester mesh and its effects in the process, the screen printer will be better equipped to make decisions concerning mesh selection for any particular printing application.

For clarification purposes a glossary has been included at the end of this report.

Testing Methodology

The nine monofilament polyester screens tested, listed in Table 1, were selected to cover a wide range of mesh counts and are from various major fabric manufacturers. The chosen meshes, therefore, represent a general survey of the mesh counts and manufacturers available on the market, and can provide a good data base on which some conclusions can be inferred.

Each mesh was tensioned with a predetermined procedure over a period of 3-5 hours to the manufacturer's recommended tension level, and adhered to a rigid steel frame. Measurements of warp and weft tension, relaxation and percent elongation were carried out and recorded during the tensioning process on each mesh. In addition, precision measurements of fabric thickness, thread diameter, mesh opening area, and mesh count were taken, both on free mesh and the final screen tension, to determine the physical change the mesh incurred during tensioning.

Table 1
Polyester Screen Printing Fabric Selected for Testing

Mesh Count/ Thread Diameter	Trade Name	Manufacturer
109/80	PES	Intern'l Fabric Corp (IFC)
158/65	Saatilene	SAATI
230/48	PES	Intern'l Fabric Corp (IFC)
254/40	Monocron	Tripette & Renaud
305/40-LE	Hitech	SAATI
305/35-LE	SR	NBC Industries
355/35	Saatilene	SAATI
390/35-TW	Saatilene	SAATI
460/30-TW	Monocron	Tripette & Renaud

**Note LE = Low Elongation, TW = Twill Weave*
All meshes are plain weave unless otherwise indicated.

Measurement Area Used Within Test Image

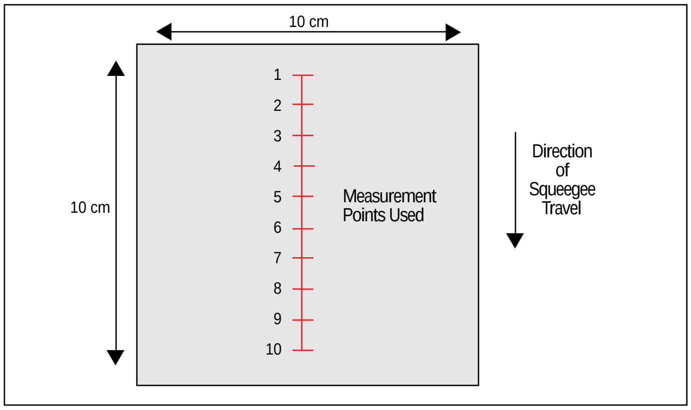

Figure 1. Only the center portion of the image was used for measurement, ensuring that our comparisions were based solely on readings representing the influence of the mesh on ink deposit and not the thickness imposed by the stencil on the edges of the print.

Manufacturer	Viscosity
Nor-Cote	10,600 cps
Midwest Coatings	12,200 cps
Naz-Dar	12,400 cps
Kolor-Cure	14,500 cps
Colonial	3,400 cps

cps = centipoise
Measured on Brookfield RV-II Viscometer.
Viscosities listed are approximate averages of 40 readings.

Figure 2. Electronic Computer Controlled Press.

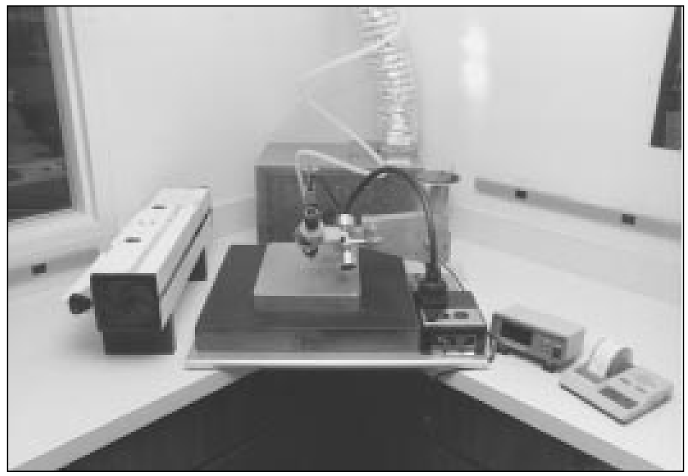

Figure 3. Electronic Micro Gauge.

These measurements are successfully being used to develop a mathematical formula for very accurate ink deposit thickness prediction for all polyester fabrics. Correlations are also being discovered linking fabric consistency and print uniformity. These areas of research are out of the scope of our discussion in this report and will be expounded on in other SPTF project reports.

The screens were stenciled with a suitable capillary film, and imaged with a 10x10 cm test square. This test pattern allowed us to print a sample that would be free of stencil thickness influence save the edges. Our measurements were taken in the center portion of the square (Figure 1) ensuring that only the deposit produced by the mesh itself would be used in our comparisons.

An electronic computer controlled screen printing press (Figure 2) was utilized for ultimate control and repeatability in the printing aspect of our testing procedure. Set up parameters for each mesh were determined on the basis of producing the best print with the least amount of squeegee pressure, and off-contact while all other variables remained the same. In this way, variation in press conditions was kept to a minimum, making comparisons between mesh counts more accurate and significant.

The five UV inks that were chosen for this investigation are listed in Table 2, along with their respective viscosities. We felt that this sampling of inks would be adequate to determine if any trends were present due to slight changes in viscosity, or if general differences in multipurpose UV inks from various manufacturers had any effect on ink deposit.

Both wet and dry samples were generated on a low cost precision glass substrate, which is first cast and then finely ground on one side to improve flatness and uniformity over the surface. In using a ground glass substrate and UV inks to determine ink deposit thickness we effectively eliminate any error caused by absorption and evaporation of the ink during measurement.

Wet and dry ink thickness measurements were made with an Electronic Micro Gauge or “EMG” (Figure 3) which combines optical and mechanical precision with

UV Wet and Dry Ink Deposit
109/80 Mesh

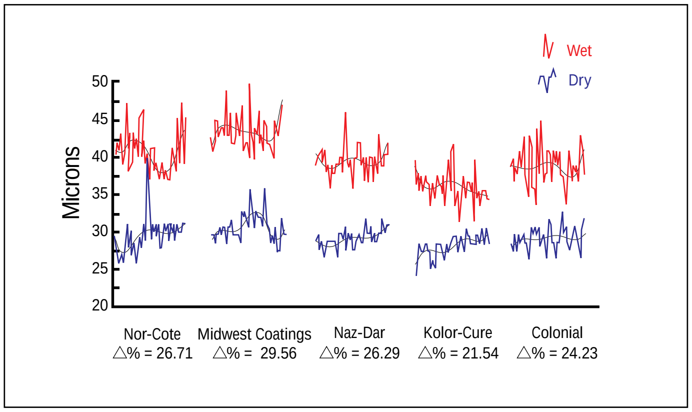

Figure 4. International Fabric Corporation (IFC)–PES

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	40.36	29.58	42.56	29.98	38.50	28.38	36.58	28.70	38.88	29.46	39.38	29.22
Standard Deviation	2.61	2.10	2.20	1.66	1.74	1.10	1.96	1.30	2.45	1.36	2.23	0.66

UV Wet and Dry Ink Deposit
158/65 Mesh

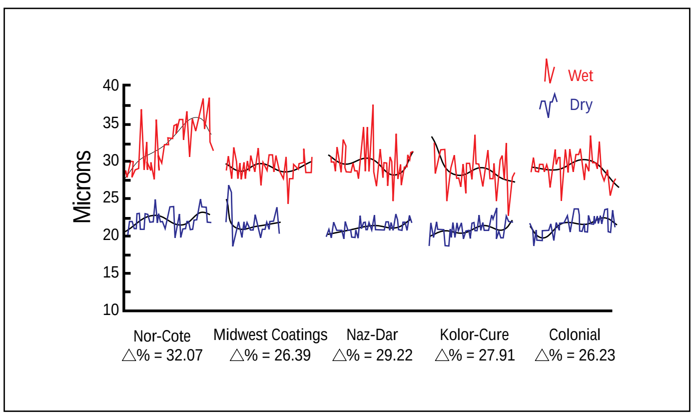

Figure 5. SAATI – Saatilene

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	32.62	22.16	29.48	21.70	30.12	21.32	29.38	21.18	29.58	21.82	30.24	21.64
Standard Deviation	3.21	1.25	1.31	1.64	2.23	0.79	2.36	1.04	1.77	1.19	1.36	0.39

UV Wet and Dry Ink Deposit
230/48 Mesh

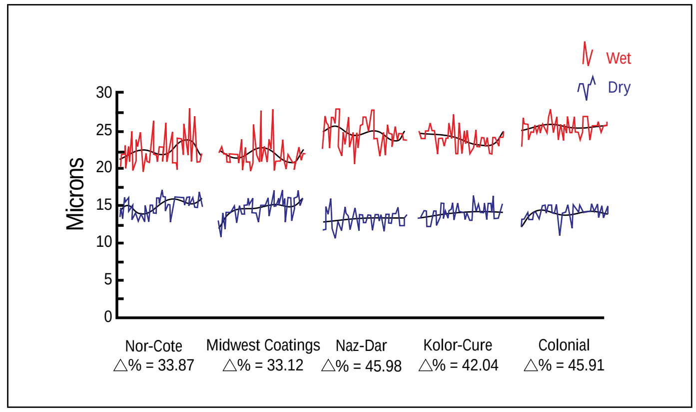

Figure 6. International Fabric Corporation (IFC)-PES

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	22.56	14.92	21.98	14.70	24.88	13.44	23.88	13.84	25.70	13.90	22.27	14.81
Standard Deviation	2.01	1.10	1.73	1.25	1.76	0.99	1.24	0.98	1.09	0.89	0.41	0.16

UV Wet and Dry Ink Deposit
254/40 Mesh

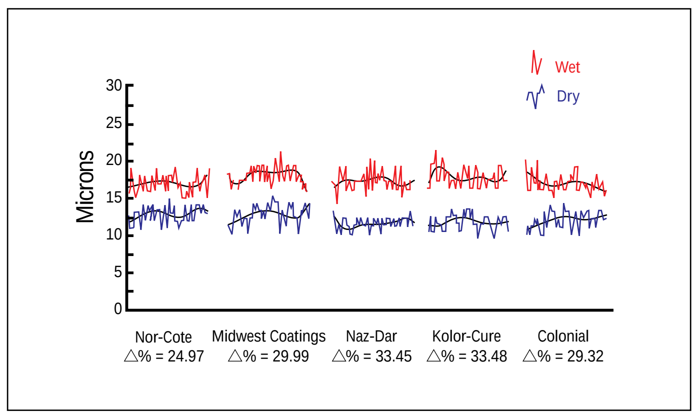

Figure 7. Tripette & Renaud – Monocron

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	16.90	12.68	17.74	12.42	17.04	11.34	18.46	12.28	16.78	11.86	17.38	12.12
Standard Deviation	1.20	1.06	1.12	1.20	1.24	0.75	1.22	1.05	1.15	1.11	0.71	0.53

electronic readouts to provide measurements accurate to plus or minus 1-2 microns. A detailed discussion of the electronic micro gauge's capability and principle of operation can be found in SPTF's research report entitled "A Guideline to Wet and Dry Ink Deposit Measurement Methods, Part One."

Five samples were printed and ten measurements taken on each sample for both wet and dry ink deposit thickness on each screen/ink combination. The calculated average and standard deviation for 50 data points are statistically sound, providing a reliable ink deposit thickness value and measure of variance useful in characterizing each polyester mesh.

Results of Research

The wet and dry ink deposit results for each screen mesh are represented graphically in Figures 4 thru 12. Each graph includes curve fitted wet and dry data for each of the five inks printed respective to that particular mesh count. The ink deposit's mean and standard deviation are provided in the data chart below the illustration for comparison purposes. Also calculated is the percent change (D%) between the wet ink height and the cured ink thickness, which is indicated under each ink's graphical representation.

Analysis of this large amount of data can be broken down into four areas of interest for discussion; UV ink

UV Wet and Dry Ink Deposit
305/40 Low Elongation Mesh

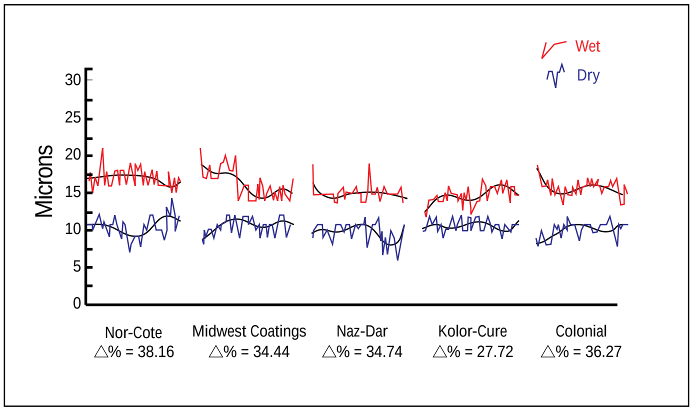

Figure 8. SAATI–Hitech

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	16.98	10.50	16.26	10.66	15.40	9.88	14.72	10.64	15.88	10.12	15.79	10.36
Standard Deviation	1.35	1.42	1.91	1.10	0.95	1.41	1.21	0.85	0.98	1.14	1.53	0.34

UV Wet and Dry Ink Deposit
305/35 Low Elongation Mesh

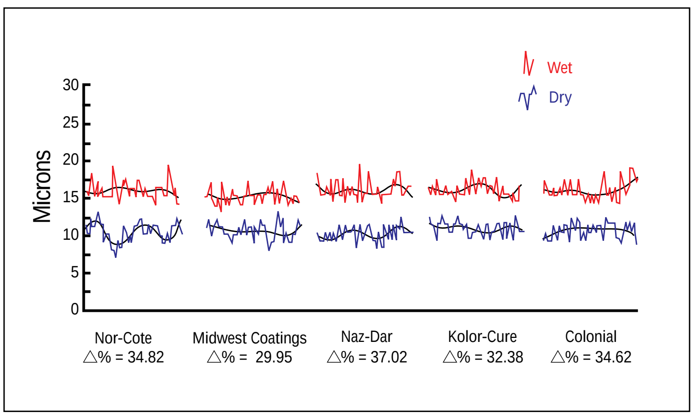

Figure 9. NBC Industries–SR

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	15.68	10.22	14.96	10.48	15.56	9.80	15.44	10.44	15.60	10.20	15.45	10.23
Standard Deviation	1.10	1.25	0.92	1.05	1.18	0.93	0.91	0.86	1.20	1.01	1.09	0.27

UV Wet and Dry Ink Deposit
355/35 Mesh

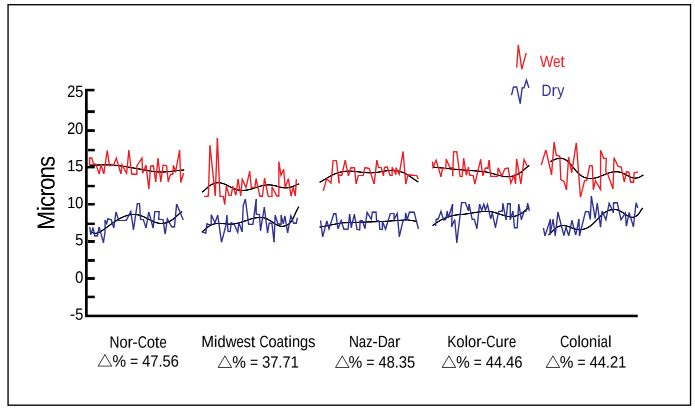

Figure 10. SAATI –Saatilene

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	14.76	7.74	13.10	8.16	13.32	6.88	13.72	7.62	14.34	8.00	13.85	7.68
Standard Deviation	1.02	1.14	1.50	1.09	0.96	0.85	0.97	1.14	1.67	1.41	0.69	0.49

UV Wet and Dry Ink Deposit
390/35 Twill Weave Mesh

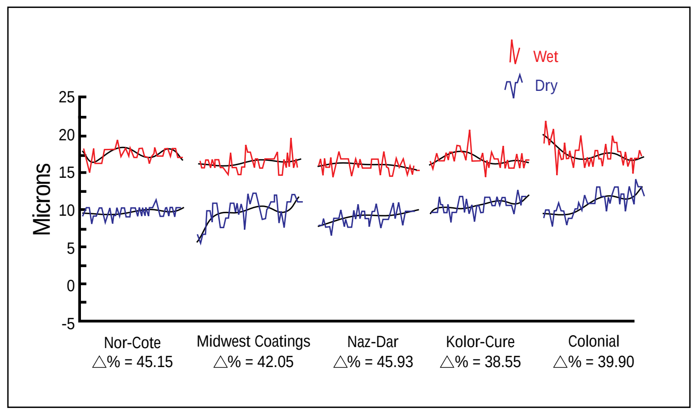

Figure 11. SAATI–Saatilene

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	17.32	9.50	15.60	9.04	15.24	8.24	16.24	9.98	16.64	10.00	16.21	9.35
Standard Deviation	0.82	0.65	1.01	1.52	0.80	0.96	1.08	0.91	1.44	1.41	0.83	0.74

shrinkage, repeatability and process control, deposit thickness trends, and hand vs. computer controlled screen printing.

UV Ink Shrinkage

The most prominent trend that can be seen throughout the data is the high percentage of shrinkage that UV ink undergoes during the curing process. The percent change (D%) from the wet ink deposit thickness to the cured thickness is not 1-3% as previously thought, but ranges from approximately 20-50%!

In looking at the calculated percent shrinkage for each ink in Figures 4-12, we can conclude that this decrease in thickness occurs in UV ink irrespective of the manufacturer and is therefore characteristic of a general UV ink formulation. We could not identify any consistent trends running through different manufacturers' inks that would indicate one ink shrinking more or less than another with all the mesh counts.

Another point worth mentioning is that percent shrinkage for one particular ink throughout the nine meshes tested did not exhibit any signs of repeatability except for remaining between 20 and 50 percent. An example of this lack of consistency can be seen in Figure 13. Here we see the wet and dry ink thickness

UV Wet and Dry Ink Deposit
460/30 Twill Weave Mesh

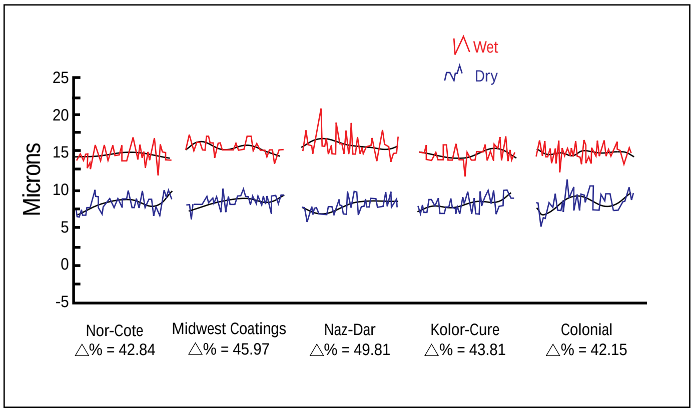

Figure 12. Tripette & Renaud – Monocron

Ink Manufacturer	Nor-Cote		Midwest Coatings		Naz-Dar		Kolor-Cure		Colonial		Total Average	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	14.66	8.38	15.40	8.32	16.14	8.10	14.70	8.26	15.42	8.92	15.26	8.40
Standard Deviation	1.00	0.88	0.83	0.79	1.36	0.95	0.91	0.96	1.01	1.23	0.61	0.31

Wet and Dry UV Ink Deposit Averages
Nor-Cote UV Ink

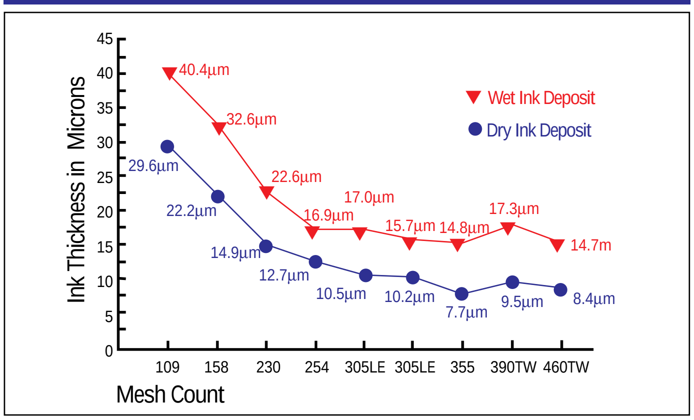

Figure 13. Wet deposit thickness as compared to cured thicknesses of a UV curable ink printed with various screen meshes.

Mesh Count	109/80	158/65	230/48	254/40	305/40 LE	305/35 LE	355/35	390/35 TW	460/30 TW
Percent Change (Δ%)	26.71	32.07	33.87	24.97	38.16	34.82	47.56	45.15	42.84

for the Nor-Cote ink depicted for each of the nine mesh counts, and the respective percent shrinkages in the accompanying table. Notice that the smallest change of 24.97% occurred with the 254/40 screen and the largest change of 47.56% came from the 355/35 mesh.

The overall average change for all meshes and inks is 36.02 percent wet to cured, and ranges from 21.54 percent change found on the 109/80 mesh with the Kolor-cure ink (Figure 4), to 49.81 percent change found on the 460/30 mesh with the Naz-Dar ink (Figure 12).

As to the exact cause for the UV ink shrinkage, SPTF speculates that it is simply an inherent characteristic to the polymerization process that takes place during the curing of any UV curable product. It stands to reason that if shrinkage is taking place in the vertical direction of the deposit, then horizontal shrinkage is also taking place.

Due to the ink's adhesion to the substrate, which would prohibit the image from shrinking, the shrinkage would have to be translated into stress horizontally within the deposit and could conceivably cause warping of the substrate that carries it. Although this has not been verified with any measurements, SPTF has in one instance, identified this phenomenon as the cause of a problem a compact disk printer was having where a printed UV coating effected the performance of the disk.

Further research in the areas of pigment loading and degree of cure as they relate to percent shrinkage is being performed to get additional insight into UV inks.

Repeatability and Process Control

There are two major areas to be examined when considering the repeatability and process capability of polyester fabric. The first is the effects of different mesh counts on deposit, and the second is the effects of different inks on ink laydown when printed with the same mesh count.

Let's look at the plots of the average, plus and minus three sigma for one ink (Nor-Cote UV) on all the mesh counts (Figures 14 and 15) in order to reveal the level of process control and capability exhibited by each screen for both wet and dry deposits.

The wet deposit variations, seen in Figure 14, show an improvement as the mesh count increases and there is a significant decrease in spread between the low mesh counts (109-230) and higher counts (254-460). In other words, the coarser fabrics produce less uniform deposits with this ink than the finer meshes which possess a higher level of process capability and repeatability in deposition consistency.

This trend, however, does not surface in the dry results of the same ink, as illustrated in Figure 15. Here we see small process spreads for all the meshes across the board, and in comparing the dry variations to the wet, we can note improvements in almost all the fabrics tested, especially in the lower mesh counts.

Overall, process control for wet deposit with this ink was maintained between plus or minus 9.63 to plus or minus 2.46 microns, with an average spread of plus or minus 4.77 microns. For dry deposit the range of process limits was between plus or minus 6.30 to plus or minus 1.95 microns, and the average spread was plus or minus 3.60 microns. These numbers characterize polyester screen printing mesh as producing extremely uniform and repeatable ink deposits, and having a high level of process capability and control.

Wet UV Ink Deposit
Nor-Cote UV Ink

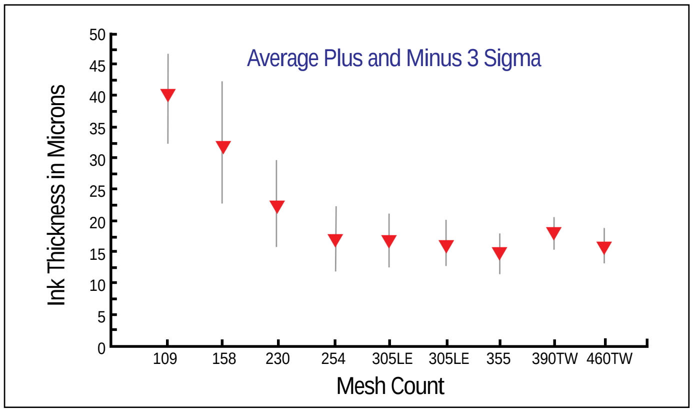

Figure 14. Variation of wet ink deposits of one ink on various meshes. Each line represents the average and process spread of 50 data points.

Dry UV Ink Deposit
Nor-Cote UV Ink

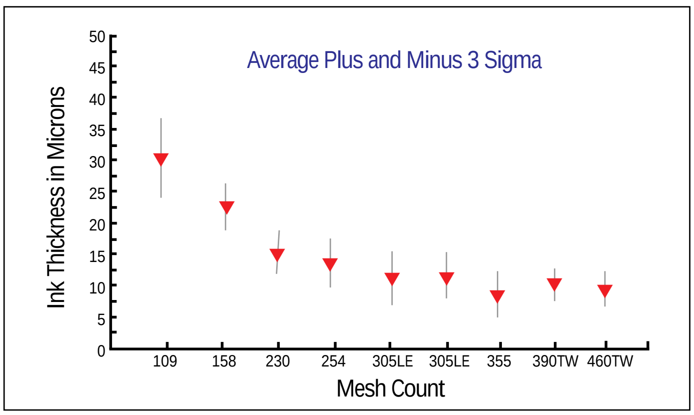

Figure 15. Variations of dry or cured ink deposits of one ink on various meshes. Each line represents the average and process spread of 50 data points.

Wet Ink Deposit Averages
Nor-Cote UV Ink

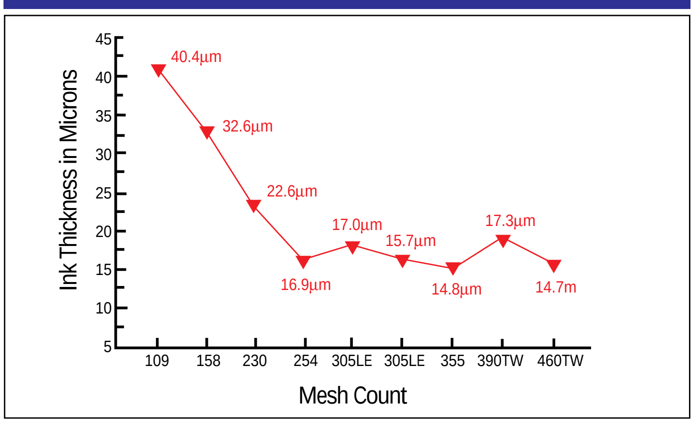

Figure 16. Wet ink deposit averages for Nor-Cote UV ink over nine mesh counts.

Having established polyester's process capability with one ink, a discussion on its ability to produce a repeatable deposit thickness with five different inks is in order. To determine the variation in thickness, the range of the average deposit heights of all five ink types was calculated for both the wet and dry deposits on each fabric, and are listed in Table 3. These numbers indicate the greatest difference between all five ink deposit thicknesses for each particular mesh count.

Table 3
Ink Deposit Thickness Variation Between 5 UV Inks

Printed on Computer-Controlled Press

Mesh•	Wet Ink Deposit Variation*	Dry Ink Deposit Variation*
109/80	5.98	1.60
158/65	3.24	0.98
230/48	3.72	1.48
254/40	1.68	1.34
305/40LE	2.26	0.78
305/35 LE	0.72	0.68
355/35	1.66	1.28
390/35 TW	2.08	1.76
460/30 TW	1.48	0.82

LE = Low Elongation, TW = Twill Weave
• All fabrics plain weave except where otherwise indicated.
** Values in microns. Variation indicated is the range of the average ink heights of all five ink types for each mesh count.*

In looking at these variations we discover that all the inks produced almost identical thicknesses on each screen, with a few exceptions seen in the wet results for the coarser meshes. Most of the ranges fall between 0-2 microns making it obvious that the range of viscosities and different manufacturers represented by these inks had almost an undetectable effect on ink deposition. It is also evident that the polyester mesh plays a major role in metering and controlling the ink deposit profile that is produced.

Deposit Thickness Trends

To more fully analyze the polyester mesh's metering function, we must take a close look at the wet ink deposit thickness produced with different mesh counts (Figure 16). A trend can be immediately identified in the thicknesses produced by mesh counts 254 through 460, which apparently generate the same deposit to within 0-2 microns of each other! A progressive decrease in ink thickness occurs only from the 109 fabric to the 254 mesh where the deposition curve becomes relatively flat to the 460 screen. This discovery puts to an end the misconception that the higher the mesh count, the lower the deposit thickness will be.

Additional points of interest are the deposits produced by the two twill weave meshes, 390/35 and 460/30. No ill effects were seen in either the uniformity or in thickness of deposit when comparing the twill weave's results to the other plain weave meshes. In fact, the process spreads of the deposits on these two screens are

Hand Screen Printing
Nor-Cote Ink Printed on Ground Glass

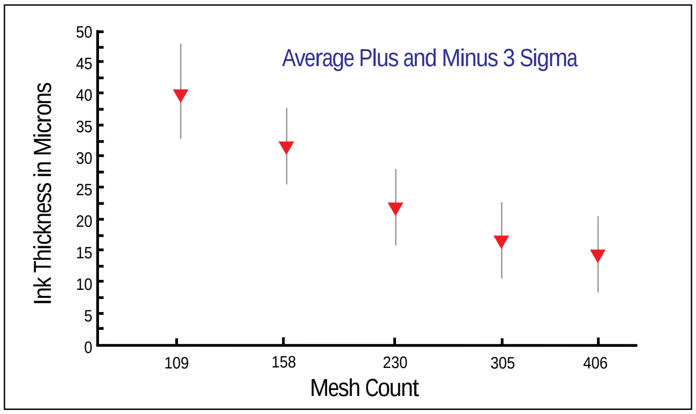

Figure 17. Variations of wet ink deposits of five polyester fabrics printed with a manual printing set up. Each line represents the average and process spread of 50 data points.

Fabric Information	109/80 IFC-PES	158/65 Saati-Saatilene	230/48 IFC-PES	305/40 IFC-PES	406/34 TW Tripette & Renaud -Moncron
Average	39.84	30.92	20.86	17.22	14.92
Standard Deviation	2.55	2.01	2.39	2.29	1.97

Hand Screen Printing

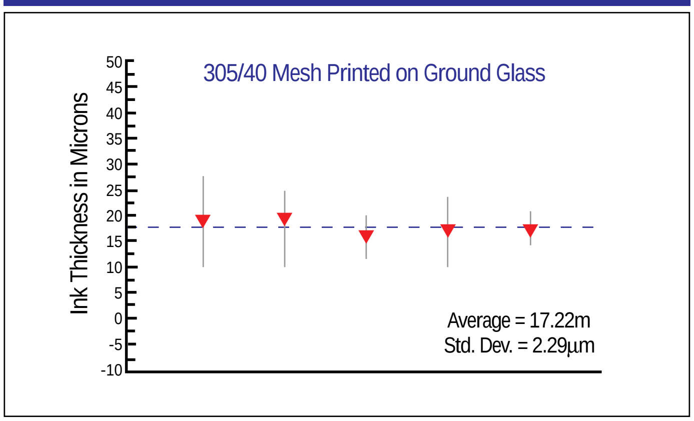

Figure 18. Ink thickness variations on hand operated proofing press.

Computer Controlled Press

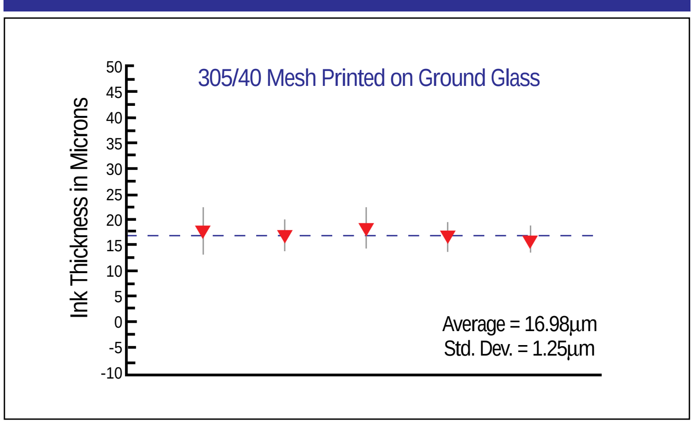

Figure 19. Ink thickness variations on computer controlled press.

smaller (Figure 14), demonstrating twill weave to be more capable of producing uniform and repeatable deposits than plain weave mesh. The deposits of the two twill fabrics are within 2 microns of the other mesh's (254-460) laydowns (Figure 16), which is not significant enough to prove that twill weave deposits more or less ink than plain weave.

SPTF's research in the area of ink thickness prediction has uncovered some relationships between the ink thickness produced from a mesh and the physical characteristics of that mesh. These correlations give further evidence that polyester screen fabric is the main element responsible for controlling ink deposit thickness. More detail on the physical characteristics of polyester mesh and their effects on ink deposit is beyond our discussion here and will be covered in other SPTF research reports.

Hand vs. Computer Controlled Screen Printing

In an effort to evaluate the full process window of polyester mesh, SPTF also studied and compared manual screen printing to the results produced on the computer controlled press. In this way the effects of press parameters on ink deposit can be examined under two extremes of control, allowing us to determine the full range of repeatability and process control that polyester mesh is capable of producing in the screen printing process.

A simple hand proofing press was utilized, where squeegee parameters (angle, speed and pressure) were allowed to float within the operators printing skill, in generating the samples for this testing.

The screens, substrate, and measurements were all handled in the same way as the experiment with the computer controlled press. After establishing the minimal effects five ink types caused in deposit on the previous experiment, only the Nor-Cote UV was printed and measured.

The wet deposit results for five screens can be seen in Figure 17. The average, plus and minus 3 sigma spread of 50 measurements is represented for each mesh, with the calculated average and standard deviation indicated below the graph for reference.

In comparing the hand screen printed results to the computer controlled results (Figure 14), we immediately notice that the higher count meshes (230-406) that were manually printed have a much greater process spread than the higher count meshes (230-460) printed with the computer controlled press. It seems logical to expect greater variation or loss of precision in the hand printed samples, but what about the average deposit thickness?

There are four mesh counts that can be directly compared in deposit thickness when printed manually and with a controlled press. Table 4 lists these meshes and their respective deposits under each print condition.

Hand Screen Printing

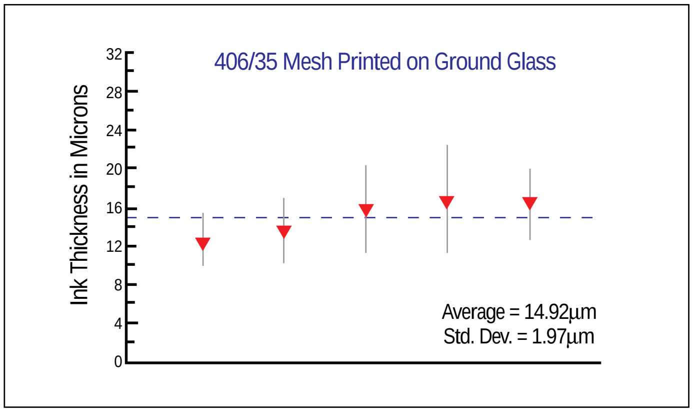

Figure 20. Variations of manually printed samples on ground glass substrate.

Hand Screen Printing

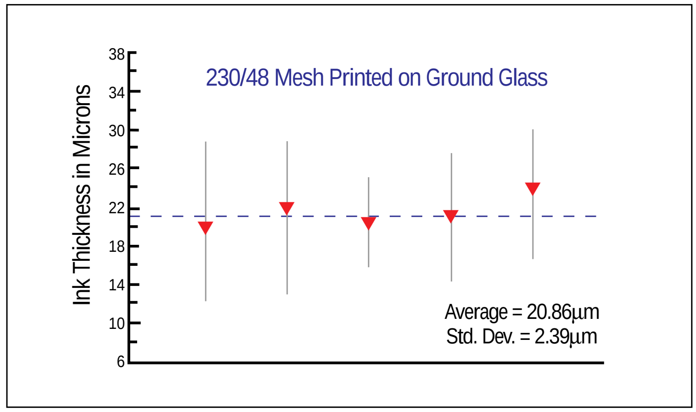

Figure 22. Ink thickness variations in lower extreme of press and substrate control.

Hand Screen Printing

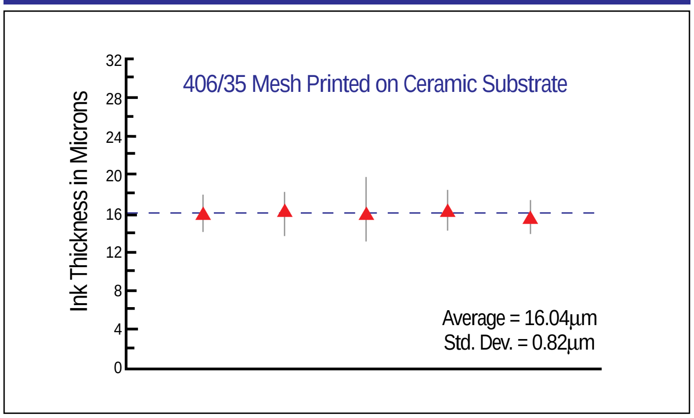

Figure 21. Variations of manually printed samples on super flat ceramic substrate

Computer Controlled Press

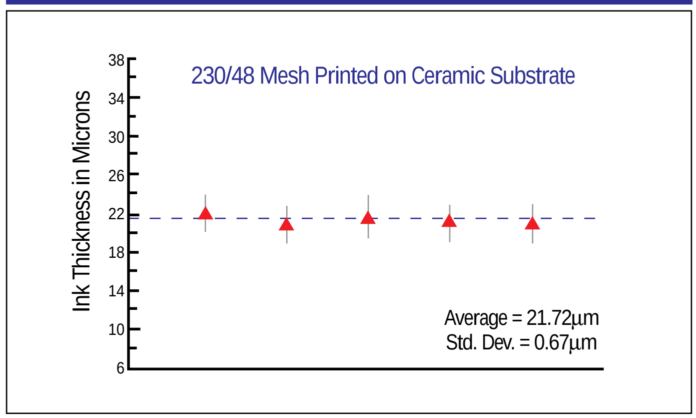

Figure 23. Ink thickness variation improvements from adding press variable control and eliminating the effect of substrate.

Table 4
Wet Ink Deposit Thickness Comparison

Mesh Count	Average Ink Deposit Hand Screen Printing*	Average Ink Deposit Computer Controlled Screen Printing*
109/80	39.84	40.36
158/65	30.92	32.62
230/48	20.86	22.56
305/40	17.22	16.98

**Values in microns*

Some quick subtraction reveals that the two deposits for each mesh are within 1.7 to 0.24 microns of each other.

Although the precision of the polyester mesh is sacrificed in the hand printing operation, its accuracy in producing the same average deposit thickness remains exceptional in both print condition extremes.

Let's look at some other comparisons to further investigate the effects these two printing methods have on deposit, and also how substrates can influence the process.

To closely investigate the difference the controlled press and the manual press make in variation of deposit, a direct sample by sample comparison needs to be examined. Figures 18 and 19 illustrate such a comparison with a 305/40 mesh printed on a ground glass substrate under both printing situations. Here 50 points are depicted in five samples with an average, plus and minus 3 sigma format.

Clearly the controlled printing condition reduces the variation seen in the sample deposits almost in half from the hand printed results. The average thicknesses, however, are within a quarter of a micron of each other.

The graphs illustrated in Figures 20 and 21 show the effect two substrates have on deposit thickness results in a hand printed 406/35 mesh. The first substrate tested, Figure 20, was the ground glass that was used throughout all our experiments mentioned in this paper. The second substrate is a 11"x7"x1/2" ceramic block, ground and polished to a flatness of 3/4 of a micron across the entire surface (Figure 21). This degree of flatness eliminates any variation caused by the substrate (including glass) and gives us a good picture of what hand screen printing with polyester mesh is truly capable of producing under the best possible conditions. As we can see, the variance is again reduced in half compared to the ground glass results, with the averages remaining within 1.12 microns of each other.

What these results actually do, without a doubt, is prove polyester mesh capable of generating extremely uniform and repeatable ink deposits, without controlling printing parameters to a great degree.

As a final point, let's examine the total process control range that is possible with the conditions set in this report. A 230/48 mesh was hand printed on a ground glass substrate (Figure 22) and that same mesh was tested with a computer controlled press on the ceramic substrate mentioned earlier (Figure 23). The first represents the conditions with the least amount of control, the second depicts the highest level of control available.

Once again, the averages are within 0.86 microns of each other, but the standard deviation, or measure of variance of the hand printed results, is 3 1/2 times that of the computer controlled deposit data.

The window of operation for hand printing in this particular example is plus or minus 7.17 microns while the computer controlled printing situation produces plus or minus 2.01 microns. Both are accurate, but one elevates the ability of the polyester mesh in laying down a uniform thickness, improving the precision of the deposit.

The process capability and repeatability attributes of a deposit generated with polyester mesh, when utilized in a manual printing situation, has proven to be better than expected. This level of control can be improved upon by controlling press parameters in printing. In SPTF's testing, a computer controlled press allowed us to put tight stipulations on our printing variables, which raised deposition uniformity to a high level of control, as we have seen. In reality, most commercial, graphic arts screen printing presses, will produce something in between these two extremes. The degree of press control that is implemented will effect how well the polyester fabric performs and; therefore, will determine the process window of the deposit.

As we have seen, substrate uniformity and flatness will also have a great influence on the deposit. Absorptive substrates, which have not been explored here, may effect deposit thickness as well as uniformity.

Conclusion

Although screen printers must consider a myriad of variables, the findings presented in this report clearly indicate one element of the process as standing out above others — the polyester mesh. The importance of a quality polyester screen can not be overly stressed.

As the screen printing industry moves into new realms of technology and control requirements increase, we believe that the emphasis a screen printer places on producing a quality screen will dictate whether or not long term success in the industry will be realized.

The excellent results pointed out in this research paper support the conclusion that polyester fabric performs in a predictable and consistent manner, making screen printing an extremely repeatable and accurate process. This surprising capability establishes the process as a precision coating and deposition method, which may very well lead to new applications for screen printing in other industries.

Definition of Terms

Accuracy - a generic concept of exactness related to the closeness of agreement between the average of one or more test results and accepted reference value.

Centipoise (cps) - one one-hundredth of a poise (metric unit of absolute viscosity), can be expressed as gm/(cm)(sec)(10^2).

cps - symbol for centipoise.

Ground Glass Substrate - a cast glass substrate where one side has been finely ground to improve flatness and uniformity.

Mean - ($\bar{x}$) a measure of central tendency equal to the sum of the observations divided by the number of observations. Also known as a statistical average.

Micron - (µm) a metric unit representing one millionth (1/1,000,000) of a meter or 0.000039 of an inch.

Percent Change (Δ%) - indicates percentage increase or percentage decrease between two numbers.

Precision - a generic concept related to the closeness of agreement between test results obtained under prescribed like conditions from the measurement process being evaluated.

Process Spread - the extent to which the distribution of individual data values of a process characteristic vary; often shown as the average, plus and minus some number of standard deviations. ($\bar{x}$ +/- 3σ)

Range - the difference between the highest and lowest values in a data group.

Repeatability - the closeness of agreement between test results obtained under repeatable conditions.

Shrink Factor - a factor determined from the average percentage decrease in wet to dry ink deposit thickness for UV curable screen printing inks.

Sigma (σ) - the Greek symbol for standard deviation.

± 3 Sigma (± 3 σ) - defines 99.73% of the area under a normal curve where only 3 of 1000 samples fall outside of that curve. These values are often the basis for control charts.

Spread - a general concept for the extent by which values in a distribution differ from one another. (See also Process Spread)

Standard Deviation - a numerical value that measures the spreading tendency or dispersion of the data. A large standard deviation represents a greater variability than a small standard deviation.

Variation - the inevitable differences among individual outputs of a process.

Viscosity - one aspect of rheology that deals with the measure of how the ink will resist flowing or internal resistance of flow. More specifically, it is a ratio of the shearing stress to the rate of the shear strain.

Δ **%** - symbol for percent change

µm - symbol for micron

σ - symbol for sigma

$\bar{x}$- symbol for mean